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Shape optimization and GRNN prediction tool implementation on bumper beam with different composite materials

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ABSTRACT

The bumper beam is an important member which is integrated in front portion and the rear portion of the vehicle. The purpose of the bumper is to absorb the impact energy in the case of crash and guard the central operational components. In low speed impacts the energy is absorbed by deflection and at higher speeds it is in the form of deformation. The virtual model of bumper beam is prepared by CATIA and investigated the outputs with steel material. From this analysis it is observed that the major stresses and deformation occurs at the middle of the bumper beam. By using Ansys 15.0 the excess material of the beam is removed by using a shape optimization technique. The upgraded bumper beam was evaluated at different thickness and speeds with altered materials like aluminum, carbon fiber epoxy and S2- glass epoxy. S2- glass epoxy shows better results than other materials and it reduces 32.86% stress and 17.75% deformation to the existing bumper beam. After attainment results a generalized regression neural network prediction tool is executed to generate a mathematical relation among input and output values. The proven prediction tool is very much grander in evaluating the output values with ±2% error.

Keywords: Shape optimization, bumper beam, stress, generalized regression neural network

1. INTRODUCTION

Bumper beams are one of the significant arrangements in any vehicle. To ensure impact behavior of any vehicle it is necessity to improve the design. The innovative design of bumper beam is simple and adequate to diminish the passenger and stay intact in low-speed effect and dissipate the kinetic energy in high speed effect. The bumper beam plays significant role to absorb the energy in crashes. The specified model is tested under frontal collision conditions and the resultant deformation and von-Misses stresses are altered cross section designs used to determine the performance of the bumper beam in crash test [1]. The point of this examination is to improve the execution of frontal impact beam (FIB) by optimizing the structural parameter utilizing crash and modal investigation new composite is produced to fit the structure parameter [2,18,19]. The bumper beam analyzed for the steel and composite material with the basic bumper design in the first phase, and then front part is modeled with the honeycomb and foam type in the second phase to compare the deformation and energy absorbed during the impact [22,23,3]. At low-velocity standards bumper beam is analyzed with aluminum and composite materials in order to compare the deflection and Von-misses stresses and reduces weight [24,25,4]. The automotive bumper to check the crash worthiness for the passenger safety to determine the deformation and energy-absorption behavior with steel and composite materials [5, 26, 27, 28]. United Nations Agreement, Regulation no. 42, the low-velocity impact simulation based on finite element analysis is carried out with carbon fiber composite and steel material to reduce the weight [6, 29, and 30]. Design a bumper for minimum weight with Glass Material Thermoplastic (GMT) materials to reduce the impact [7, 8, and 9]. The M220 material can minimize the bumper beam deflection, impact force and stress distribution and also maximize the elastic strain energy than other materials [10.20, 21]. The speed is according to regulations of Federal Motor Vehicle Safety Standards, FMVSS 208- Occupant Crash Protection whereby the purpose and scope of this standard specifies requirements to afford impact protection for passengers [11 12 and 13]. The car bumper was modeled by NX8.5 and analyzed with different loads on different materials and sandwich panels are used to impact loads [14 15 16 and17]. The Structure, shape and different materials are used over a bumper and compared the results with existing one. In the present work Localized Stress variation and deformation of the Eicher 15.0 bumper beam is considered for analysis with steel as a material. Shape optimization technique is implemented for getting best model on weight consideration. A GRNN prediction tool is executed to establish a relation among input and output parameters.

2. ANALYTICAL METHOD

The specification of the Eicher 15.0 bumper beam are considered for this analysis and the detailed drawing is as shown in Fig.1. As per dimensions of Eicher 15.0 bumper beam the virtual model of bumper beam is prepared by using CATIA and is shown in Fig.2. The pressure applied on the front portion of the beam is calculated by using below mathematical equations. 2 mm thickness bumper beam and steel material is considered for this analysis at altered speeds by Ansys workbench 15.0.

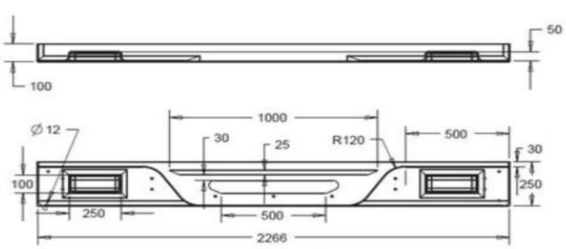


Figure 1 Eicher 15.0 bumper beam specifications in mm

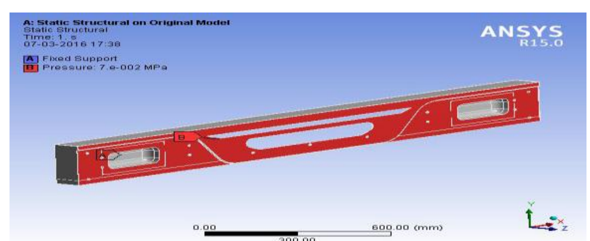


Figure 2 Virtual model and boundary conditions of bumper beam

The localized stress variation and deformation are calculated in static condition of bumper beam with 2mm thickness at a speed of 2.5 kmph is as shown in the Fig.3. From the above static analysis, it is noticed that the stresses and deformations are developed and maximum at middle of the bumper beam. The stresses generated within the body are more because of deformation at the middle portion is 204.83 mm. From the localized outcomes the stress and deformations are very less, from this by closing the middle portion with some extra material the stress will decreases, at the same time the weight of the bumper will increases. The primary goal of this work is to reduce the weight and increase the strength, to accomplish that a shape optimization is applied and find out that the model can further improvised.

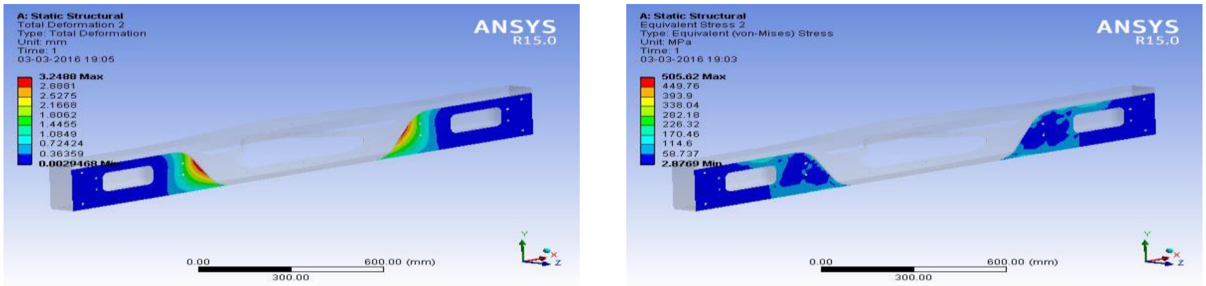


Figure 3 Localized stress variation and deformation of the bumper beam

3. SHAPE OPTIMIZATION TECHNIQUE

The investigation file must exist as a different element. The catalogue for optimization is not a part of the ANSYS classical database. The methodology of ANSYS optimization is in two ways as a group run or interactively via Graphical User Interface (GUI). The methodology will rely upon analyzers ANSYS skill and the favorite for interacting with the ANSYS program. The optimization is begun by generating an ANSYS command Input file and acquiescing it as a batch job. This might be a more productive strategy for complex investigations (for nonlinear) that require extensive run time. On the other hand, the interactive features of optimization offer more flexibility and instant feedback for review of loop

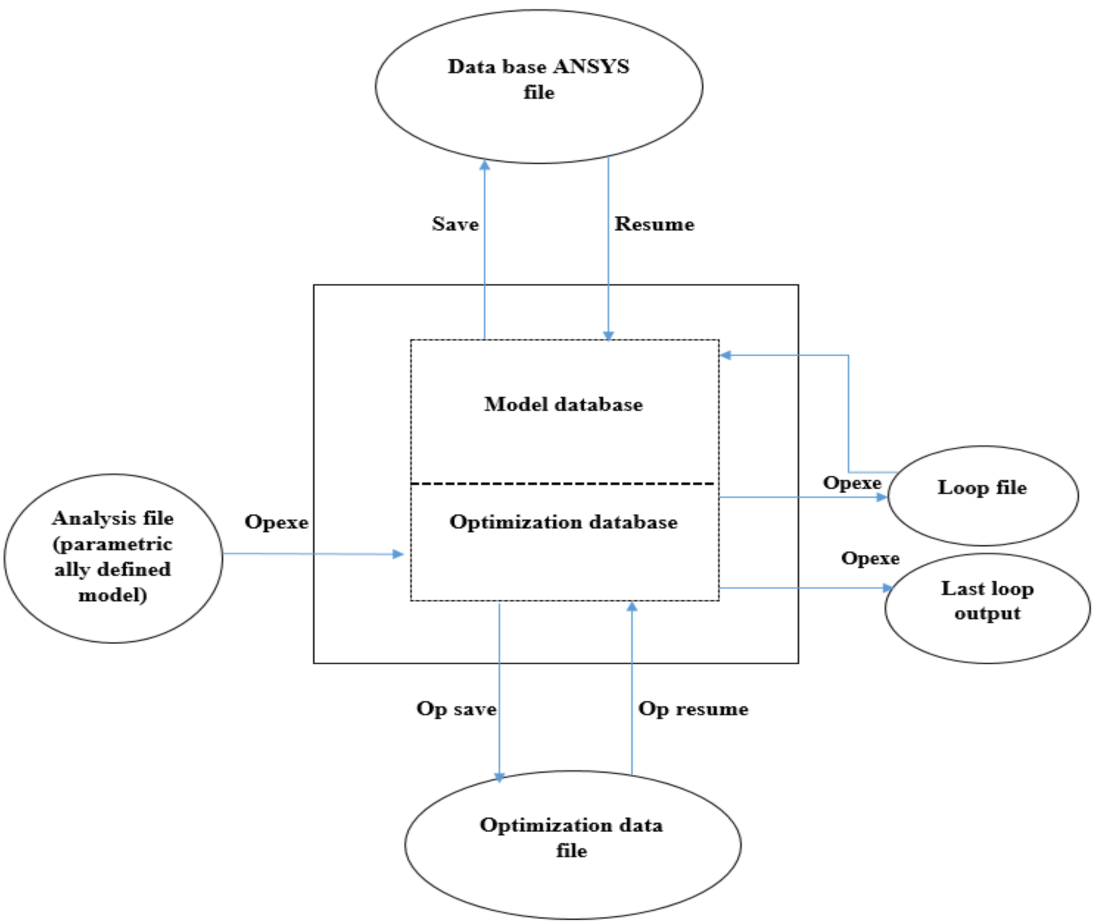
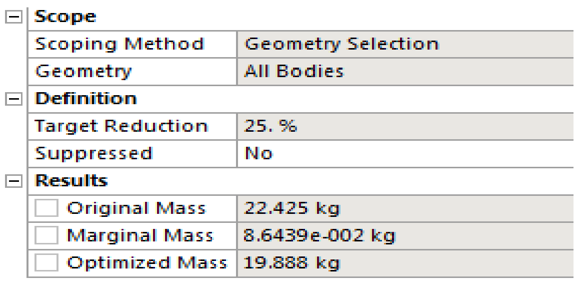


Figure 4 Design shape optimization flow chart of ANSYS

Finite element analysis has been utilized to implement optimization and maintaining stress and deformation levels and reaching high implement optimization and maintaining stress and deformation levels and reaching high results. When executing optimization through the GUI, it is significant to initially build the study file for your model. At that point all activities inside the analyzer can be performed intelligently, allowing the freedom to probe the design space before the real optimization is finished.

Stiffness

The basic model of the foundation which has been modelled and studied above is conceded to do shape optimization in ANSYS workbench from Fig.5. As observed from the fig 6, the red color shows the amount of material that can be removed, by maintaining all the limitations.



Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Target Reduction	25. %
Suppressed	No
Results	
Original Mass	22.425 kg
Marginal Mass	8.6439e-002 kg
Optimized Mass	19.888 kg

Figure 5 Total details of shape finder

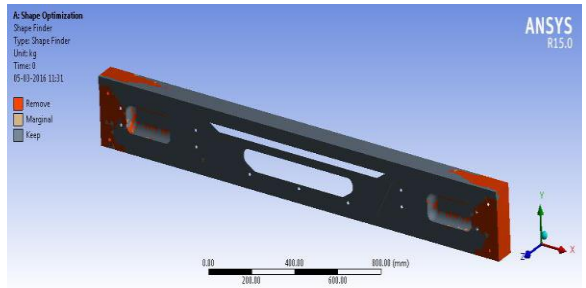


Figure 6 Material removals from bumper beam

The mass of the basic foundation model is 22.425 kg and after shape optimization the mass of the foundation is 19.888 kg which shows the decrease in mass of foundation by 2.6kg. The refined new model geometry after shape optimization is as shown in Fig.7.

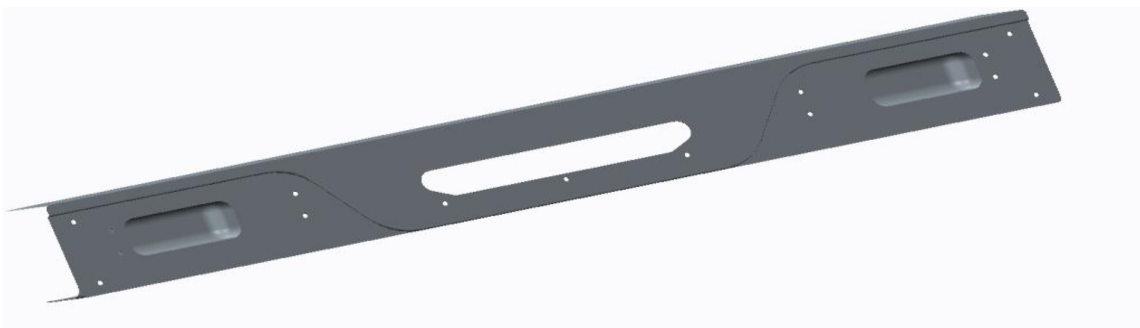


Figure 7 Modified and improvised bumper beam

Material properties

Material	Aluminum	Carbon fiber epoxy	S2 Glass fiber epoxy
Young's modulus (Gpa)	68.9	85	86.9
Poisson's ratio (1/m)	0.33	0.15	0.23
Density (Kg/m^3)	2720	1600	2460

Structural analysis of modified beam with different materials

In this analysis four different materials considered to calculate best output values at altered speeds and thicknesses. The Fig. 8 & 9 indicates the variation of stress and deformations at 2mm thickness. Different materials are considered to investigate how the young's modules will effects the performance of the beam and analyzed. In this analysis conventional materials like aluminum and magnesium where considered for it, in carbon family Carbon Fiber Epoxy and Poly Ether Imides are considered for analysis, in Glass Fiber epoxy, GMT (Glass Mat Thermo set), SMT (Short Mat Thermo set) and S2 Glass fiber where considered form glass fiber family. The results shows reduced stresses and deformations. The bumper beam not showing any yield when it is crushed at 8 kmph. The Fig.10 shows the performance of the bumper beam at altered geometries and materials. The speed can be changed from 2.5 kmph to 8 kmph and the parameters are calculated. As per European standards the developed stress is allways less than the yield value.

Here, in this project work aluminum, carbon fiber and S2 glass fiber epoxy were taken in to study. Steel is the material which is used in making of existing bumper, aluminum is one of the best suited materials in automobile industry because of its strength to weight ratio.

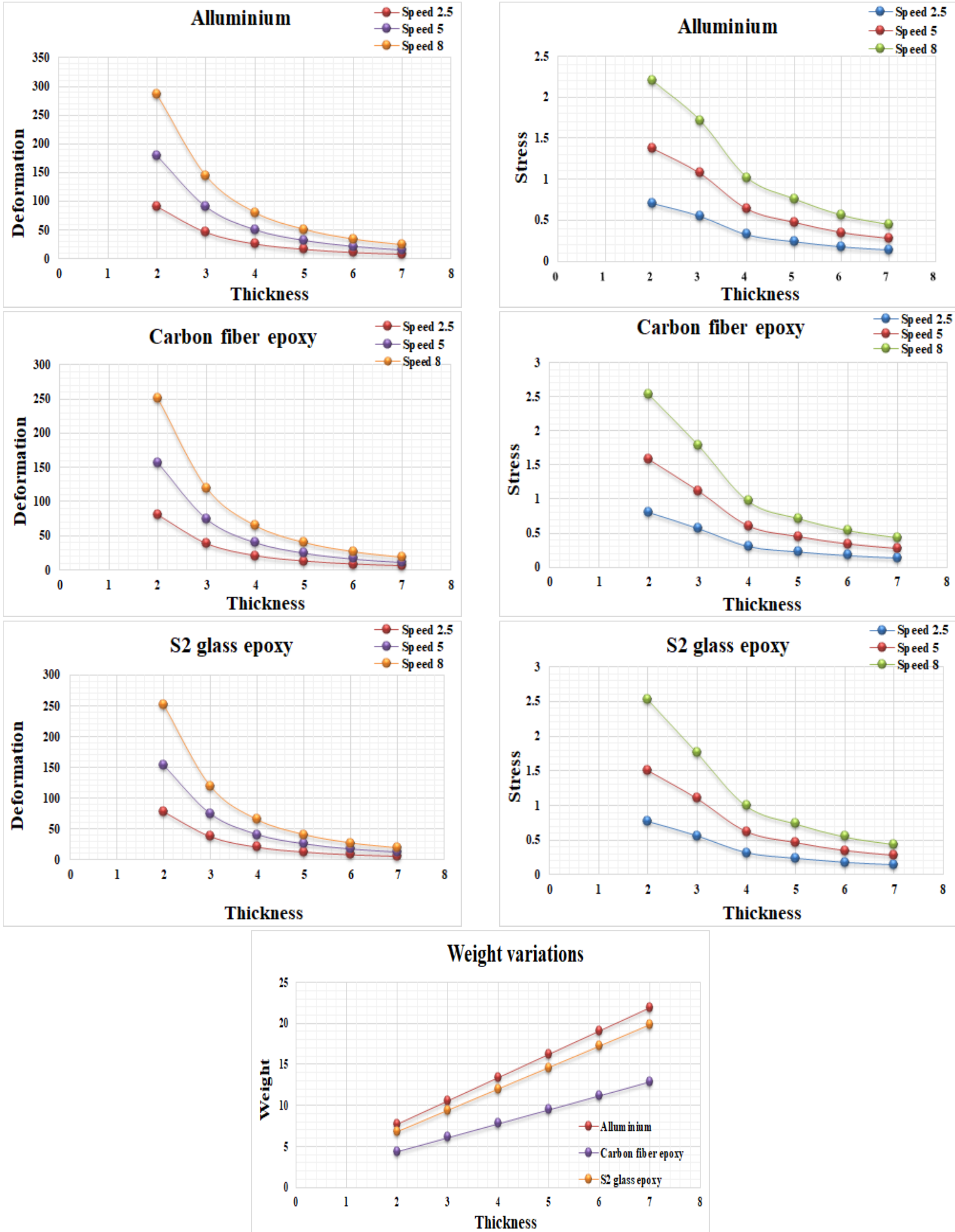


Figure 8 Stress, deformation and weight variations at different geometries, speeds and materials

Implementation of GRNN

The above input and output values are nonlinear in nature and there is no specific relation between them. In order to attain a relationship among these parameters, GRNN is executed in this analysis. Firstly, 65 numerical datasets are engaged for training the established GRNN tool and the remaining 7 numerical datasets are operated to test the established tool. The proposed model assessments output values as a function of input values according to the equation (6).

$$\hat{Y}(X)=\frac{\sum_{i=1}^{n} Y^{i}\exp\left(-\frac{D_i^2}{2\sigma^2}\right)}{\sum_{i=1}^{n}\exp\left(-\frac{D_i^2}{2\sigma^2}\right)} \qquad (6)$$

Here (Xi, Yi) is the ith data set point; $D^2 i$ = (X− Xi) ^{T} (X− Xi), and σ = smoothing parameter.

In this analysis, 72 numbers of numerical datasets have been considered and the equivalent outputs are measured. A complete numerical datasets are showed in Table 1.

Table 1 Input and output constraints for implementation of GRNN

Symbolic representation	Input name	Input weigh
X1	Aluminium	10
	Carbon fiber epoxy	20
	S2 glass fiber epoxy	3
X2	Speed (Kmph)	2.5
		5
		8
X3	Thickness (mm)	2
		3
		4
		5
		6
		7
Outputs		
Symbolic representation	Output name	Output weight
Y1	Deformation	As per experimentation
Y2	Stress	As per experimentation
Y3	Weight	As per experimentation

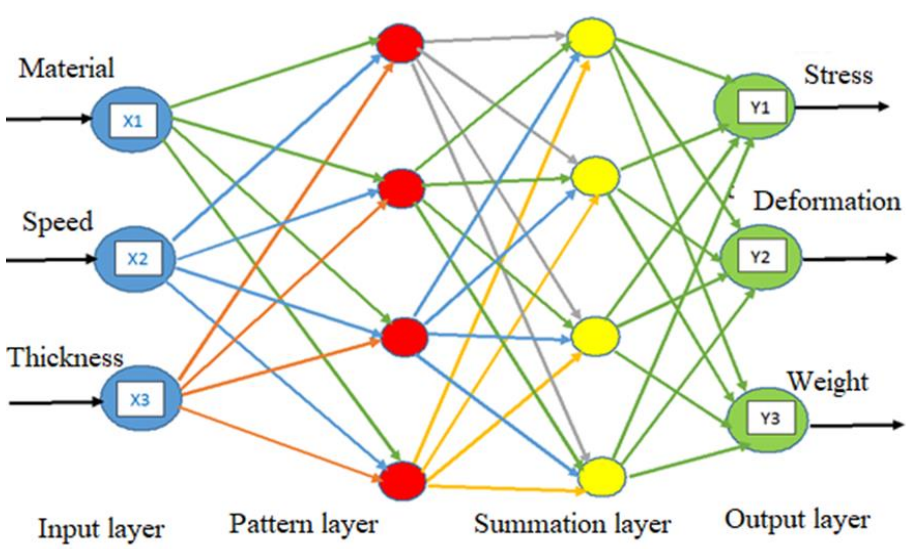
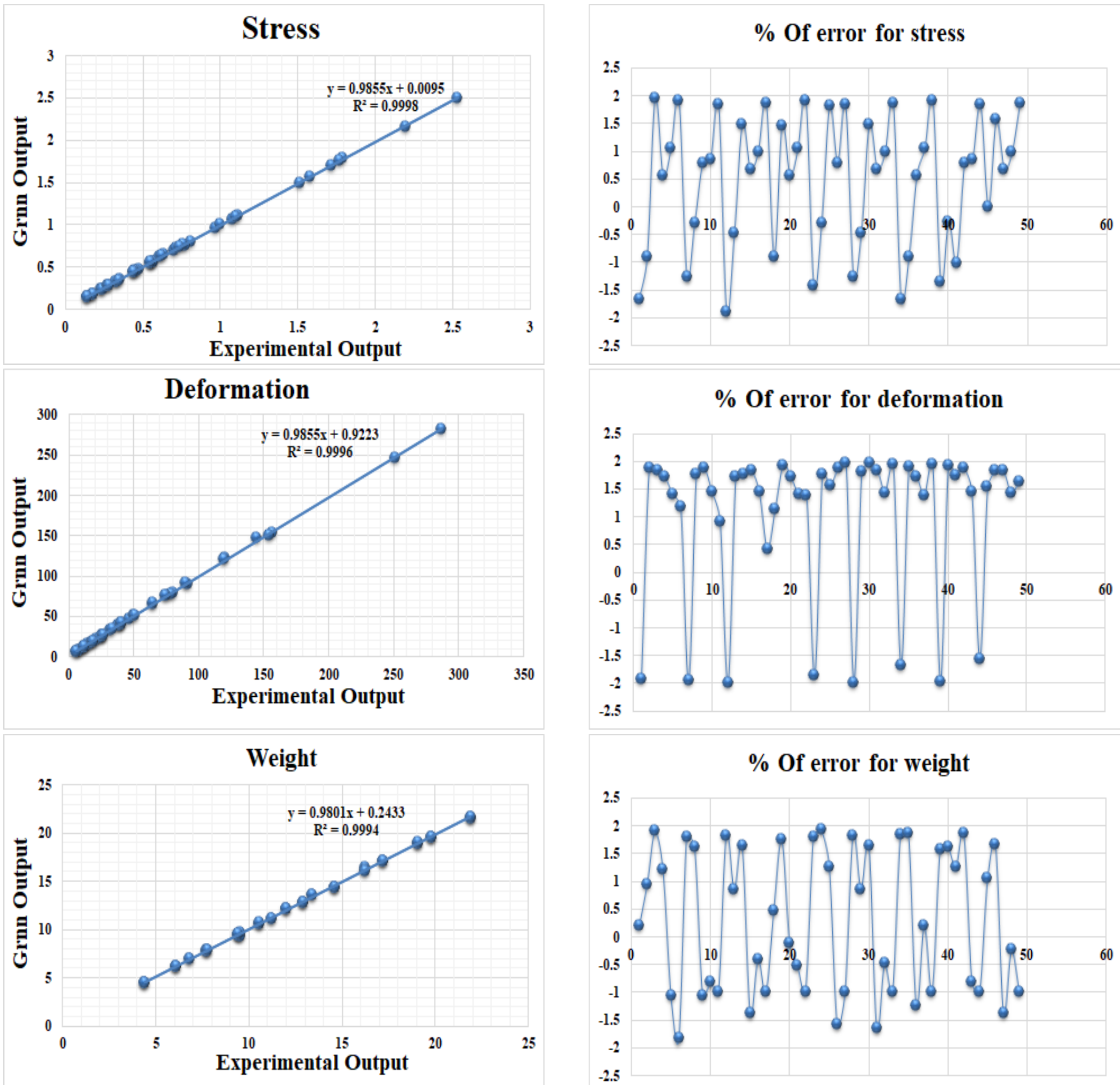
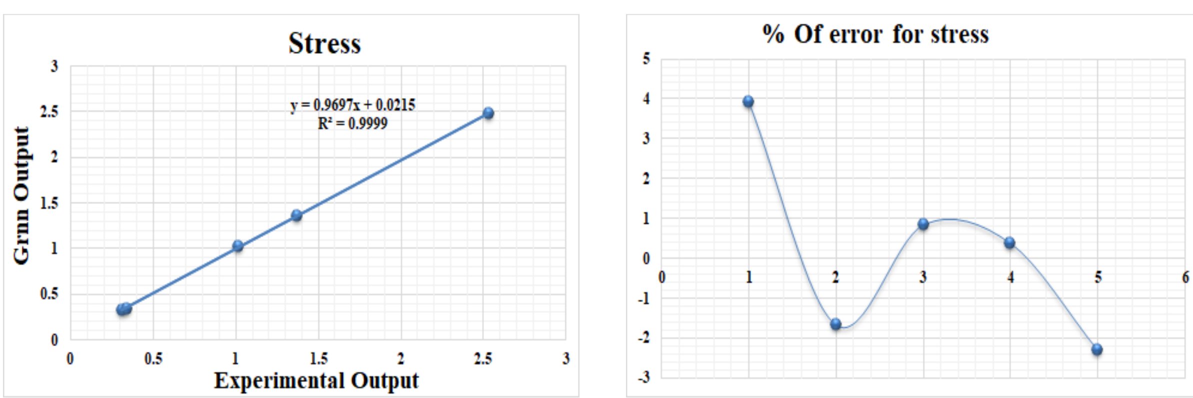


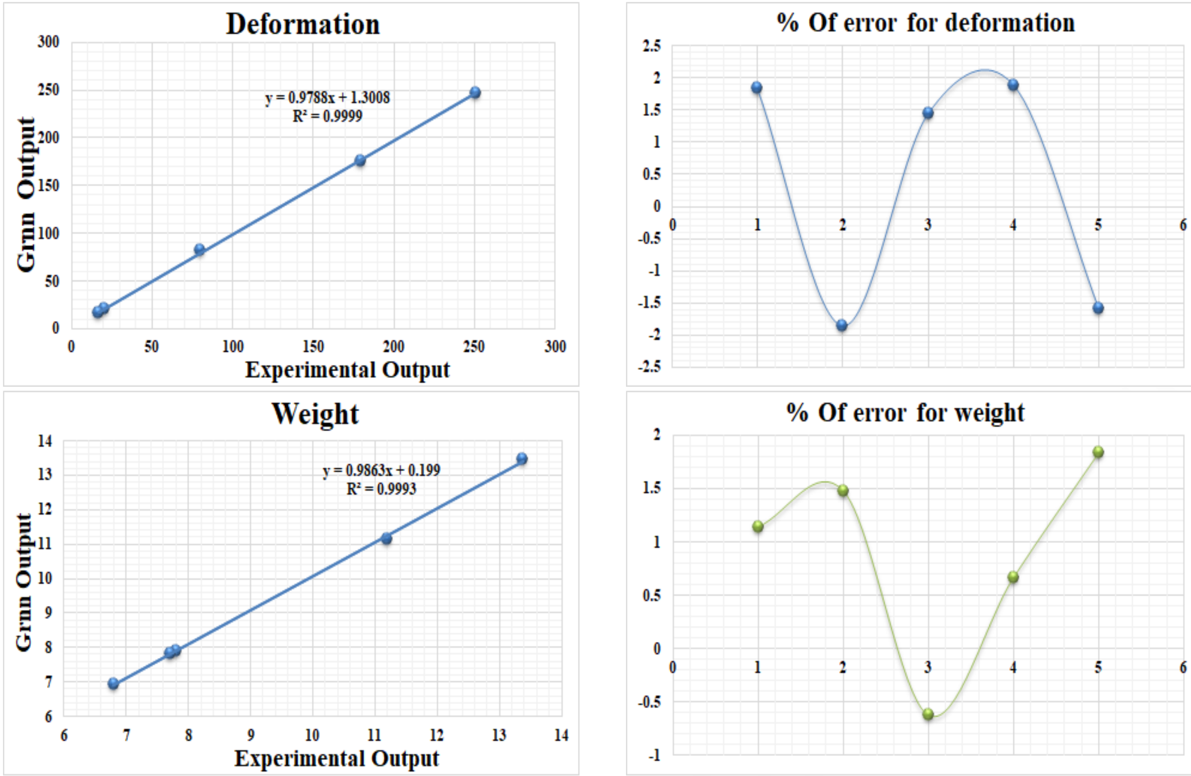
Figure 9 distinctions of GRNN output values

Formerly executing the GRNN, standard deviation and scaling factor of every input parameter is to be intended. Fig. 10 signifies the distinction of GRNN output values with respect to the numerical output values for the trainee and test datasets. The established GRNN tool is very much supercilious in estimating the output values with ±2% error. The significant purpose of the developed model is to evaluate the outputs for the given input values without performing the experiments



Trainee datasets and percentage of errors





Tested datasets and percentage of errors

Figure 10 Variation of GRNN output values with respect to actual experimental results for trainee & test datasets and also percentage of error

4. CONCLUSION

In the current study numerical analysis are conducted on the bumper beam to evaluate the stress and deformations at different thickness and speeds with altered materials like aluminum, carbon fiber epoxy and S2- glass epoxy. S2- glass epoxy with 7mm thickness beam shows better results than other materials and it reduces 32.86% stress and 17.75% deformation to the existing bumper beam. The input and output parameters shows a nonlinear relation. A generalized regression neural network prediction tool is executed to generate a mathematical relation among input and output values. The proven prediction tool is very much magnificent in evaluating the output values with ±2% error. The main advantage of this GRNN prediction tool is calculating the outputs by a given input value without conducting experimentation.

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Conflicts of Interest: The authors declare no conflict of interest.

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Appendix

S1 no	Experimental stress	GRNN stress	% Of error	Experimental deformation	GRNN deformation	% Of error	Experimental weight	GRNN weight	% Of error
1	0.70179	0.690173454	-1.655273855	91.519	89.75485433	-1.927627786	7.7	7.715095157	0.195657427
2	0.54845	0.543483164	-0.905613264	46.039	46.91681677	1.871006662	10.54	10.64021907	0.94188914
3	0.32466	0.331111535	1.948447563	25.566	26.04576248	1.841998197	13.38	13.64	1.906158366
4	0.24177	0.243145904	0.565875913	16.152	16.43519835	1.723120982	16.22	16.42	1.218026789
5	0.17833	0.180218476	1.047881662	10.753	10.90549207	1.398305224	19.06	18.85978093	-1.050467303
6	0.14166	0.144438413	1.923597146	7.514	7.604041223	1.184123287	21.9	21.49849048	-1.833376784
7	0.80832	0.798192721	-1.252879938	80.151	78.59479178	-1.941595513	4.4	4.480754143	1.802244454
8	0.57031	0.56870025	-0.282258747	38.223	38.91062521	1.767191371	6.1	6.200131132	1.614984103
9	0.2287	0.230510192	0.785298051	12.846	13.0918869	1.878162429	9.5	9.399999999	-1.052631587
10	0.1734	0.17488226	0.847576152	8.519	8.643818169	1.444016597	11.2	11.10986887	-0.804742252
11	0.1391	0.141698675	1.833944734	5.96	6.01538862	0.920782076	12.9	12.77124586	-0.998094132
12	0.77152	0.756940016	-1.889774003	78.488	76.92551941	-1.990725447	6.8	6.926918101	1.832244864
13	0.56319	0.560561644	-0.466690838	38.04	38.70514618	1.71849547	9.4	9.480200555	0.845979519
14	0.31767	0.329155811	1.489475433	20.712	21.08499871	1.769024109	12	12.2	1.639344271
15	0.23529	0.236881426	0.671824024	12.928	13.16965482	1.834936606	14.6	14.4	-1.369863021
16	0.17541	0.177152025	0.983350506	8.57	8.695521583	1.443519882	17.2	17.12979944	-0.408142762
17	0.14022	0.142886235	1.865984543	5.99	6.01547711	0.423526	19.8	19.6030819	-0.994535864
18	1.0734	1.063819207	-0.892565062	90.104	91.1437055	1.140732095	10.54	10.59021907	0.474202352
19	0.63541	0.644821965	1.459622291	50.036	51.02033434	1.929298092	13.38	13.62	1.762114546
20	0.47318	0.475872388	0.565779516	31.611	32.16540538	1.723607627	16.22	16.19999999	-0.123304637
21	0.34901	0.352706531	1.048047192	21.046	21.34434823	1.397785642	19.06	18.95978093	-0.525808331
22	0.27724	0.282677871	1.923698816	14.707	14.912168	1.37584288	21.9	21.68490484	-0.982169665
23	1.582	1.55971952	-1.408374186	156.87	153.9568647	-1.857037848	4.4	4.480754143	1.802244454
24	1.1162	1.113047178	-0.282460329	74.809	76.16164936	1.776024242	6.1	6.220013113	1.929467206
25	0.60594	0.617182405	1.821569303	40.443	41.08743342	1.568444078	7.8	7.900000001	1.265822794
26	0.4476	0.451149637	0.786798232	25.142	25.62396745	1.880924358	9.5	9.35011	-1.577789474
27	0.27224	0.277332788	1.836345408	11.67	11.90491353	1.973248533	12.9	12.77124586	-0.998094132
28	1.51	1.49111138	-1.25090196	153.61	150.5647833	-1.982433905	6.8	6.926918101	1.832244864
29	1.1022	1.097063399	-0.466031681	74.45	75.83049256	1.820497946	9.4	9.480200555	0.845979519
30	0.62172	0.631113856	1.488456642	40.537	41.35415685	1.975996882	12	12.2	1.639344271
31	0.4605	0.463614245	0.671731904	25.303	25.77650374	1.836958747	14.6	14.36	-1.643835624
32	0.34331	0.346718558	0.983090724	16.782	17.0268334	1.437926791	17.2	17.11979944	-0.466282297
33	0.27443	0.279648819	1.866204602	11.729	11.96184663	1.946577634	19.8	19.6030819	-0.994535864
34	2.1986	2.162206438	-1.655306196	286.72	281.9313813	-1.670137647	7.7	7.845095157	1.849501552
35	1.7182	1.702640301	-0.905581344	144.23	147.0373845	1.909299798	10.54	10.74021907	1.864199106
36	0.75743	0.761738817	0.565655446	50.601	51.48917493	1.724974096	16.22	16.02	-1.23304563
37	0.55867	0.56458727	1.048070054	33.699	34.17511977	1.393176584	19.06	19.09780932	0.197977269
38	0.44379	0.45249423	1.923611364	23.541	24.01062366	1.955899461	21.9	21.68490484	-0.982169665
39	2.5324	2.498233373	-1.349179722	251.1	246.1550153	-1.969328824	4.4	4.470754143	1.582599731
40	1.7867	1.781660812	-0.282038836	119.75	122.1149408	1.936651512	6.1	6.200131132	1.614984103
41	0.96994	0.960124236	-1.011997032	64.722	65.87640265	1.752376584	7.8	7.900000001	1.265822794
42	0.71648	0.722162246	0.786837917	40.245	41.01545979	1.878461905	9.5	9.679999999	1.859504125
43	0.54338	0.548004011	0.843791493	26.691	27.08239672	1.445207114	11.2	11.10986887	-0.804742252
44	0.43579	0.44394134	1.836130033	18.681	18.38788923	-1.569031485	12.9	12.77124586	-0.998094132
45	1.7644	1.76427598	-0.007029042	119.17	121.028306	1.535430864	9.4	9.500200555	1.054720419
46	0.9952	1.011036529	1.566365693	64.889	66.09725933	1.828002163	12	12.202	1.655466318
47	0.73713	0.742115762	0.671830746	40.503	41.26104285	1.837187822	14.6	14.4	-1.369863021
48	0.54955	0.555005388	0.982943297	26.864	27.25574816	1.437304743	17.2	17.15979944	-0.233724157
49	0.43929	0.44764405	1.866226072	18.774	19.08694845	1.639593961	19.8	19.6030819	-0.994535864